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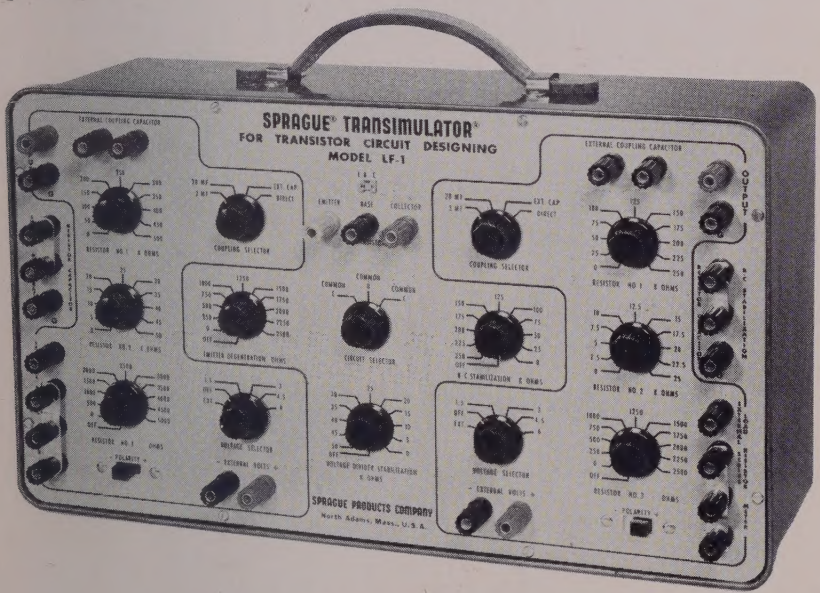
OPERATING MANUAL



MODEL LF-1 TRANSIMULATOR*

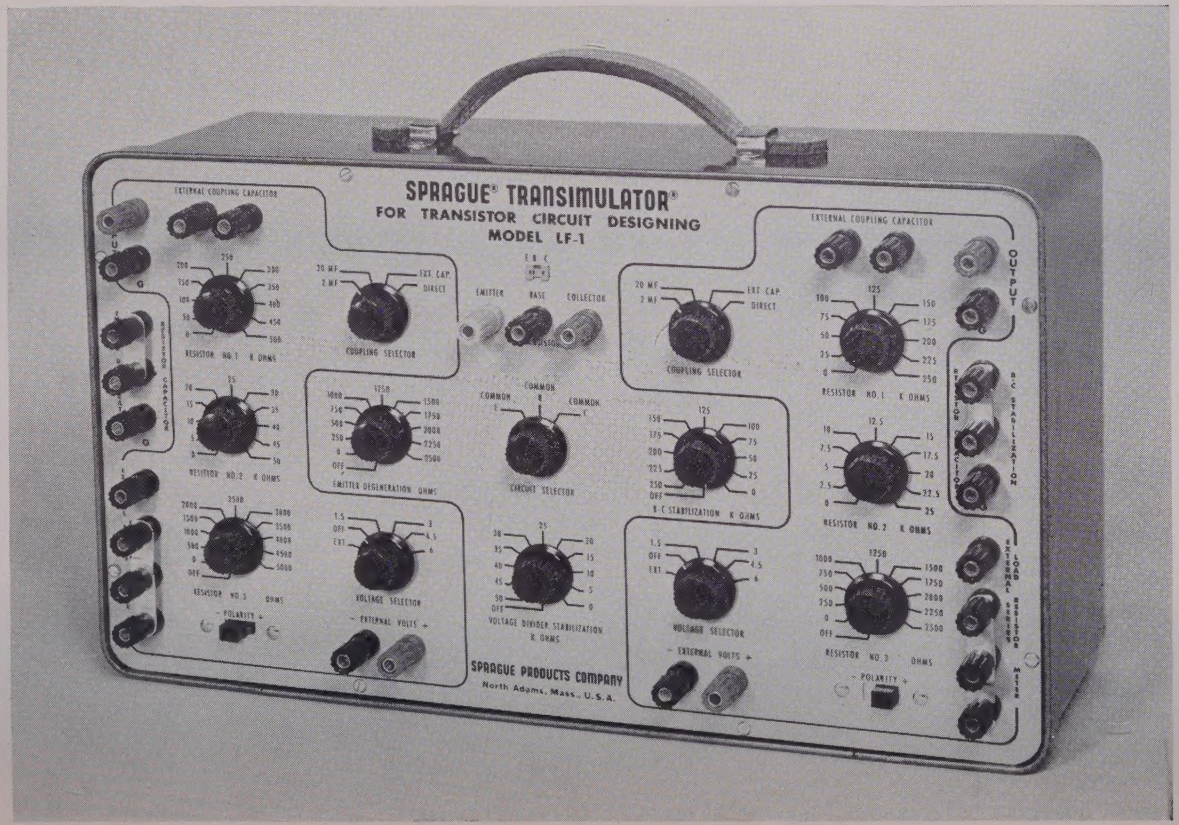
FOR TRANSISTOR CIRCUIT DESIGNING

★ TRADEMARK

SPRAGUE PRODUCTS COMPANY

North Adams, Mass.

PRICE: 50 CENTS



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Sprague Products Company
North Adams, Mass.

Operating Manual

MODEL LF-1

TRANSIMULATOR

For Transistor Circuit Designing

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1. General Description

1.1 Purpose and Usefulness. The Model LF-1 Transimulator is an instrument designed basically to eliminate the "breadboard" stage in the design of low and medium power transistor circuitry. With it, one may simulate all types of amplifier stages short of high power audio output as well as multivibrator, switching, phasing, Class A and B push-pull and many others when using cross-coupled transimulators. Circuits may be simulated stage-by-stage for cascade operation or multiple instruments may be used to get simultaneous multi-stage operation.

1.1.1 The Transimulator may also be used to permit the selection of individual transistors for best performance with established circuit parameters or for "incoming inspection" tests of transistors in a particular circuit as well as for general demonstrations of the effect of varying circuit parameters when used as a classroom aid in teaching.

1.2 Circuits for Simulation. The range of possible circuit configurations includes those utilizing PNP, NPN, and Surface Barrier Transistors, operated in common base, common emitter or common collector circuits with a choice of input and output circuits, degeneration, and stabilization. While the Model LF-1 is designed primarily as a timesaver in R-C circuit design, provision has been made for direct coupling or transformer coupling or a combination thereof.

1.3 Connections are available to permit measurement of selected parameters by use of external meters.

1.4 Experience has shown that the Transimulator may be best used for circuit design purposes with a signal generator and an oscilloscope although alternate signal sources such as phonograph pickups, microphones, etc. and alternate output devices such as a-c vacuum-tube voltmeters, calibrated amplifiers, etc. may be used.

2. Operation

2.1 Power Supply. The Model LF-1 Transimulator may be operated from an internal power supply consisting of 8 size AA penlight cells or from external dry or storage batteries. A-C power supplies with adequate filtering and a-c line isolation transformers may also be used. The internal supply will be adequate for most applications but external sources should be used for heavy duty applications, such as transistor inspection, where voltages above 6 volts are required, or where the current drain will be more than 20 ma.

2.1.1 How To Install Internal Batteries. Turn instrument upside down on bench with face toward you and slide door toward you. Install cells in battery clips taking care to observe polarity as indicated. Both Input and Output Voltage Selector Switches should be turned to "OFF" position before installing batteries.

2.1.2 External Power Supplies. External batteries or power supplies should be connected to the appropriate terminals marked "EXTERNAL VOLTS". The INPUT power source is connected to the binding posts at the left bottom center while the OUTPUT power source is connected to the binding posts at right bottom center.

2.2 Voltages Available. Internal d-c voltages of 1.5, 3, 4.5, and 6 volts may be utilized by setting the Input and Output Voltage Selector Switches as indicated by the panel markings. Other voltages must be secured from an external supply as described in Section 2.1.2. *Always keep selector switches in "OFF" position until the Transimulator circuit has been set up and the transistor inserted.*

2.3 Setting for Transistor Type and Common Element. The Input Polarity and Output Polarity switches must be set as shown in the following table:

Transistor Type	Common Element	Input Polarity	Output Polarity
NPN	Emitter	+	+
	Base	—	+
	Collector	+	—
PNP	Emitter	—	—
	Base	+	—
	Collector	—	+
Surface Barrier	Emitter	—	—
	Base	+	—
	Collector	—	+

2.4 Input Circuit.

2.4.1 The shorting link should be across the External Series Meter Terminals or else a microammeter or milliammeter of the proper range should be connected between the binding posts.

2.4.2 Input Resistors 1, 2, and 3 should be advanced to maximum resistance setting.

2.4.3 The Input Coupling Selector Switch should be rotated to the desired position. If an External Coupling Capacitor is to be used, it should be connected to the binding posts so marked at the top left.

2.4.4 There should be no connection across the Input External Load Terminals, unless transformer input is being used (See 6.1-6.5), or if a power transistor is being used (see 7.5.4.4). (See also 3.7, 3.10, and 3.26).

2.5 Stabilization Circuit. The Emitter Degeneration, Voltage Divider Stabilization, and B-C Stabilization controls should be in the "OFF" position.

2.6 Output Circuit.

2.6.1 The shorting link should be across the External Series Meter Terminals or else a microammeter or milliammeter of the proper range should be connected between the binding posts.

2.6.2 Output Resistors 1, 2, and 3 should be advanced to maximum resistance setting.

2.6.3 The Output Coupling Selector Switch should be rotated to the desired position. If an External Coupling Capacitor is to be used, it should be connected to the binding posts so marked at the top right.

2.6.4 There should be no connection across the Output External Load Terminals, unless transformer output is being used (see 6.1—6.5), or if a power transistor is being used (see 7.5.4.4). (Also see 3.20, 3.23, and 3.32).

2.7 Transistor Connections and Circuit Set-up.

2.7.1 Set the Circuit Selector to the common element for the circuit selected, E, B, or C (Emitter, Base, or Collector).

2.7.2 Connect signal generator or other signal source to input terminals and oscilloscope or other monitoring device to output terminals.

2.7.3 Set-up circuits as shown in section 3.

2.7.4 Insert Transistor into socket or else connect elements to binding posts at top center, taking care to observe the marked connections. See Section 5.

2.8 General Notes.

2.8.1 Meters used to measure input or output circuit currents should be properly bypassed for a-c by a shunt capacitor of a value appropriate for the circuit frequency. (See 2.8.2.2)

2.8.2 When using batteries, either internal or external, and particularly at high current drains, it may be desirable to bypass the supply source for a-c. This may be easily accomplished by shunting a capacitor of proper value from the upper Meter terminal to the lower Emitter Degeneration Capacitor terminal marked G on the Input side or between the upper Meter terminal and the lower B-C Stabilization Capacitor terminal marked G on the Output side, or both, as required.

2.8.2.1 *CAUTION:* As large values of capacity will be required, the charging current will be large and damage to sensitive meters will result unless they are shunted until the capacitor is charged. A low impedance power source will not need bypassing and if meter impedances are low in relation to resistance values in the transistor circuit, the meters may be unbypassed.

2.8.2.2 If polarized electrolytic capacitors are used as the bypass capacitors, care should be taken to observe capacitor polarity. The pole connected to the meter terminal should agree with the polarity setting of the input or output polarity selector switch, as appropriate. The capacitor voltage rating should be equal to or higher than the maximum power supply voltage.

2.8.2.3 If battery bypass capacitors are used in accordance with 2.8.2, they will also bypass input and/or output current meters and individual meter bypass capacitors will not be required.

2.8.3 Coupling Capacitors. The internal coupling capacitors used in the Model LF-1 are special low-leakage current electrolytics of non-polar design. If the instrument is not used regularly, it may be desirable to re-age the capacitors from time to time in order to maintain minimum leakage. Capacitors should be re-aged at least once a year. This may be done as follows:

2.8.3.1 Input Capacitors.

(a) Set Input Resistors at maximum value.
(b) Make certain that the Voltage Selector switch is in the OFF position and that there is no transistor in the instrument.
(c) Set Coupling Selector switch at 2 μF position.
(d) Set V-D Stabilization Control to 50,000 Ω.
(e) Apply 100 volts d-c for about 20 minutes across Input Terminals, then reverse polarity of applied voltage for another 20 minutes

(f) Set Coupling Selector switch at 20 μF position and repeat step (e)

2.8.3.2 Output Capacitors.

(a) Set Output Resistors at maximum value.

(b) Set B-C Stabilization Control to 0 Ω.

(c) Follow steps (b) to (f) under 2.8.3.1 except in step (e) connect voltage to Output Terminals.

2.8.3.3 After re-aging the capacitors per 2.8.3.1 and 2.8.3.2, *the capacitor sections must be discharged completely before using the Transimulator for circuit setup.* To do this, connect a jumper across the Input Coupling Capacitor terminals and rotate the Input Coupling Selector to the 2 μF and 20 μF positions. Then follow the same procedure for the Output Capacitors. This procedure should be followed at any time that the coupling capacitors may have been charged due to circuit design work.

2.8.3.4 External Capacitors. Make certain that all external coupling capacitors you may use are of transistor circuit grade. Low-voltage capacitors designed for electron-tube circuitry may not always be suitable for use in transistor circuits. The Sprague Littl-Lytic, Verti-Lytic, and Cera-Lytic series of miniature aluminum electrolytics and all Sprague Tantalex tantalum electrolytics have ultra-low leakage current characteristics suitable for transistor work.

2.9 Measurements. The table on page 5 shows how to measure various circuit parameters using the Transimulator. It should be noted that the instrument panel indications for resistance are only approximations and are intended to serve only as a guide in setting up circuitry. Absolute measurements should be made where it is intended to duplicate the simulated circuit in actual practice.

3. Description of Controls and Terminals

3.1 Input Voltage Selector. In EXT position, it connects in the potential applied to the Input External Volts terminals. In OFF, no voltage is applied to the input circuit while the 1.5, 3, 4.5, and 6 volt positions apply these voltages from the internal batteries to the input circuit.

3.2 Input External Volts Terminals. External batteries and power supplies should always be connected with due regard for polarity. The external voltage applied to these terminals is only connected to the input circuit when the Input Voltage Selector is in the EXT position.

3.3 Output Voltage Selector. In EXT position, it connects in the potential applied to the Output External Volts Terminals. In OFF, no voltage is applied to the output circuit while the 1.5, 3, 4.5, and 6 volt positions apply these voltages from the internal batteries to the output circuit.

3.4 Output External Volts Terminals. External batteries and power supplies should always be connected with due regard for polarity. The external voltage applied to these terminals is only connected to the output circuit when the Output Voltage Selector is in the EXT position.

3.5 Input Resistor 1. This 500,000 Ω tapped resistor is connected in series with Input Resistors 2 and 3.

TABLE OF MEASUREMENTS

Common Element					Meter	Transistor		Supply Volts		Measurement Between Terminals	
E	B	C	Circuit	Parameter	To Be Used	In Ckt.	Out Ckt.	On	Off	From	To
					STATIC MEASUREMENTS						
√	√	√	Input	Resistance	Ohmmeter	√			√	Top Input Meter	Top Input Ext. Load
√	√	√	Output	Resistance	Ohmmeter	√			√	Top Output Meter	Top Output Ext. Load
√			Emitter	Resistance	Ohmmeter		√		√	Bot. Em. Deg. Cap.	Top Em. Deg. Res.
√			V-D Stab.	Resistance	Ohmmeter		√		√	Top Input Ext. Load	Bot. Em. Deg. Cap.
√			B-C Stab.	Resistance	Ohmmeter		√		√	Top Input Ext. Load	Top B-C Stab. Res.
					DYNAMIC MEASUREMENTS						
√	√	√	Input	Volts*	VTVM	√		√		Top Input Meter	Bot. Em. Deg. Cap.
√	√	√	Output	Volts*	VTVM	√		√		Top Output Meter	Bot. B-C Stab. Cap.
√	√	√	Input	Element V.†	VTVM	√		√		Top Input Ext. Load	Bot. Em. Deg. Cap.
√	√	√	Output	Element V.†	VTVM	√		√		Top Output Ext. Load	Bot. B-C Stab. Cap.
√			Emitter	Element V.†	VTVM	√		√		Top Em. Deg. Res.	Bot. Em. Deg. Cap.
√	√	√	Input	Current	μA or MA	√		√		Bot. Input Meter	Top Input Meter
√	√	√	Output	Current	μA or MA	√		√		Bot. Output Meter	Top Output Meter
√	√	√	Input	Signal	A-C VTVM or 'Scope**	√		√		Top Input	Bot. Input
√	√	√	Output	Signal	A-C VTVM or 'Scope**	√		√		Top Output	Bot. Output

Make sure measurement is made under load conditions.
*When transformers are used, signal measurements are made across the appropriate transformer winding.
Measured between active transistor element and circuit common or ground connection.

3.6 Input Resistor 2. This 50,000 Ω tapped resistor is connected in series with Input Resistors 1 and 3.

3.7 Input Resistor 3. This 5,000 Ω variable resistor is connected in series with Input Resistors 1 and 2. A series switch permits the entire string of input resistors to be removed from the circuit when the knob is turned to the OFF position.

NOTE: The total resistance provided by Input Resistors 1, 2, and 3 in series is 555,000Ω. This value may be increased by removing the link across the terminals marked Series Resistor and connecting the desired resistance in its stead.

If a very low value of resistance is required, disconnect the internal resistors by turning Input Resistor 3 to OFF; then, connect the desired low resistance externally between the Input External Load Terminals.

If transformer input is required, turn Input Resistor 3 to OFF; then, connect the transformer secondary across the Input External Load Terminals.

3.8 Input Meter Terminals. Replace the link normally across these terminals with a microammeter or milliammeter if you wish to measure d-c input current. If the meter reads backwards, reverse the connections.

3.9 Input Series Resistor Terminals. Replace the link normally across these terminals with the necessary value of resistance if you wish to extend the internal series resistance up to some high value required in a particular input circuit.

3.10 Input External Load Terminals. These terminals are normally open. If you wish to connect an external input circuit resistor, inductor, or transformer, use these terminals. Make sure that the Input Resistor 3 has its switch turned to OFF in order to disconnect the internal input circuit resistor string.

3.11 Emitter Degeneration Control. This variable resistor permits the introduction of up to 2,500 ohms resistance in series with the transistor emitter when the Circuit Selector switch is in the Common E position. The OFF position of this control shunts the resistance element out of the circuit completely so as to avoid including any residual hop-off resistance. This control is not normally used in common base or collector circuits, but it may be used if your circuit requires series base or collector resistance.

3.12 Emitter Degeneration Capacitor Terminals. To eliminate signal degeneration introduced by the use of the Emitter Degeneration Control, while retaining d-c stabilization, connect an appropriate capacitor across these terminals. (See 3.13)

3.13 Emitter Degeneration Resistor Terminals. These terminals are normally connected by a link. If it is desired to connect a resistor in series with the Emitter Degeneration Control in order to extend the range of the internal control, substitute this resistor for the link. For full elimination of degeneration, a bypass capacitor of appropriate value should be connected in this case between the top Degeneration Resistor terminal and the bottom Degeneration Capacitor terminal. If only partial elimination is required, the capacitor may be left connected as in Section 3.12.

3.14 Voltage Divider Stabilization Control. This 50,000Ω variable resistor permits a resistance to be connected between base and ground, thus forming a voltage divider with the Input Circuit Resistor string. Generally, the smaller the resistance of the divider circuit so formed, the greater the stability. But too low a setting for this control will increase

current in the divider network and shunt part of the input signal. This control is usually used in grounded emitter circuits with the Circuit Selector set on Common E. The switch on the control permits it to be cutout of the circuit when the knob is turned to OFF.

3.15 Base-Collector Stabilization Control. This 250,000Ω variable resistor may be effectively connected between transistor base and collector. Since this control feeds back both d-c bias and signal from collector to base, the base bias is stabilized. The amount of bias stabilization effected is dependent on the d-c resistance of the collector load being proportional to that load. However, it is accompanied by signal degeneration. The degeneration is greater with a fairly high load impedance in the collector circuit, since this results in increased signal feedback. See sections 3.16 and 3.17 for methods of degeneration elimination. When the collector load impedance is low, the signal degeneration in the feedback loop is small and is not usually bypassed. This control is usually used in grounded emitter circuits with the Circuit Selector set on Common E. The OFF position of the knob removes the control from the circuit.

3.16 B-C Stabilization Capacitor Terminals. These terminals are used only for a bypass capacitor when a resistor is connected between the B-C Stabilization Resistor Terminals (3.17). The bypass capacitor serves to eliminate signal degeneration from the B-C stabilization feedback loop.

3.17 B-C Stabilization Resistor Terminals. The link across these terminals is removed when it is necessary to introduce an external resistor in series with the Base-Collector Stabilization Control in order to extend the range of the control. When using a bypass capacitor in the B-C stabilization circuit, an external resistor equal to ½ the total stabilization resistance necessary is usually connected here; the remaining ½ of the required resistance is supplied by adjusting the B-C Stabilization Control to the necessary value.

3.18 Output Resistor 1. This 250,000Ω tapped resistor is connected in series with Output Resistors 2 and 3.

3.19 Output Resistor 2. This 25,000Ω tapped resistor is connected in series with Output Resistors 1 and 3.

3.20 Output Resistor 3. This 2,500Ω variable resistor is connected in series with Output Resistors 1 and 2. When the control knob is turned to the OFF position, it opens a switch and removes the entire resistor string from the output circuit.

NOTE: All 3 output resistors in series total 277,500Ω. When a larger value of resistance is necessary, open the link across the Output Series Resistor Terminals and connect the added resistance between them. When a very low value of resistance is necessary, turn Output Resistor 3 to the OFF position and connect the required low value resistor across the Output External Load Terminals. If an output transformer primary winding, a relay coil, or other external load device is required, it is connected in the same fashion as a low value resistor.

3.21 Output Meter Terminals. A microammeter or milliammeter of proper range is substituted for the link normally across these terminals when it is necessary to read the d-c current in the output circuit. If the meter reads backwards, reverse the connections.

3.22 Output Series Resistor Terminals. The link across these terminals is removed when it is necessary to introduce an external resistor in series with the Output Resistor string in order to extend the range of resistance in the output circuit.

3.23 Output External Load Terminals. These terminals are used to

connect an output transformer, external output resistor, relay coil, etc. Output Resistor 3 must be in the OFF position when using these terminals.

3.24 Input Polarity Selector. This switch is set in either the + or — position in accordance with the table on page 2. This is done whether the internal or an external input voltage source is used. The only exception is in the case of a few circuits using B-C stabilization which may require a small bias voltage of polarity opposite to that normally applied.

3.25 Output Polarity Selector This switch is set in either the + or — position in accordance with the table on page 2. This is done whether the internal or an external output voltage source is used.

3.26 Input Signal Terminals. These terminals are used for introducing the input signal from the source. The red terminal is the "hot" terminal except when series transformer input is used. In the latter case, the transformer is connected to the Input External Load Terminals as previously described. The shunt transformer input is connected to the input signal terminals (see 6.5).

3.27 Input External Coupling Capacitor Terminals. These terminals are used to connect an external capacitor between the input signal and the transistor input element when the Coupling Selector switch is in EXT CAP position.

3.28 Input Coupling Selector. This switch may be used to connect a 2 or a 20 μF internal capacitor in series between the input signal and the transistor input element or it may be used to switch in an external coupling capacitor or for making a direct connection from input terminal to transistor in a direct-coupled circuit.

3.29 Circuit Selector. This switch sets up the Transimulator for Common Emitter, Common Base, or Common Collector operation by switching the transistor elements as required.

3.30 Transistor Socket. This is used for most common 3-pin straight line base transistors. Element connections are as marked.

3.31 Transistor Terminals. These are used for all transistors which do not fit the transistor socket.

3.32 Output Signal Terminals. These terminals are used to couple the Transimulator to the output device or next stage (the red terminal is the "hot" terminal) except when transformer output is used. The transformer is connected instead to the Output External Load Terminals as previously described.

3.33 Output Coupling Capacitor Terminals. These terminals are used to connect an external coupling capacitor between the transistor output element and the red Output Signal Terminal.

3.34 Output Coupling Selector. This switch may be used to connect a 2 or a 20 μF internal capacitor in series between the transistor output element and the Output Signal Terminals, or it may be used to switch in an external coupling capacitor, or for making a direct-coupled output connection.

4. Circuit Design

4.1 General Information. The data given in this section and in section 5 on set-up will assist you in mastering proper and rapid operation of the Model LF-1 Transimulator. By observing the proper procedure, you will learn the method of set-up for any circuit you wish to

design or test. It is suggested that a standard text on transistors and transistor operation in various circuit configurations will prove of great assistance in your further investigation of transistor circuit design. A study of the application of the LF-1 to circuit design will suggest many more applications than those set forth in this manual.

4.1.1 While the circuits shown make use of internal bias and output voltages applied to R-C coupled circuits, it should be recognized that the LF-1 allows the use of external voltages and loads and choice of coupling circuits to permit maximum flexibility. A study of the function of each control as set forth in section 3 will provide the information to allow you to gain maximum use of the LF-1.

4.1.2 The circuits shown are based on the use of PNP or Surface Barrier Transistors. To use NPN transistors in the same circuit design, reverse the polarity of the Input and Output Polarity Selector Switches from that shown in the table of set-up instructions in Section 5.

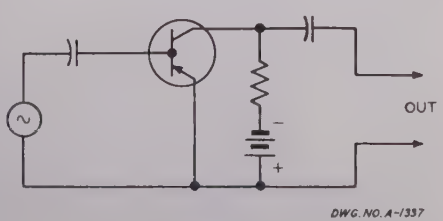
4.1.3 Signal provided by an audio generator will be most useful by providing the various levels necessary in circuit design. An output indicator, such as an oscilloscope, will permit careful adjustment of the LF-1 for maximum gain and minimum distortion. A vacuum-tube voltmeter will permit measurement of transistor element potentials and final determination of the absolute value of circuit parameters. Microammeters or milliammeters will permit measurement of circuit currents. Note that the panel calibrations for the various built-in adjustable resistance controls are as accurate as it is possible to make them without individual calibration for each resistor. Absolute measurements of each control used should be made at the final setting for optimum operation of a particular circuit. (See page 5, Table of Measurements).

4.2 Circuit Design. Circuit design using the Model LF-1 Transimulator is based on determining the most efficient operating parameters for a particular application. In order to consider completely the requirements for such a design, an orderly approach to the problem must be undertaken. Therefore, we shall first examine grounded or common emitter operation since it is the most popular for general-purpose amplifiers. (See Section 5 for Circuit Set-up Chart).

4.2.1 Grounded Emitter. This circuit exhibits medium to moderate input impedance and moderate output impedance ranging from 100 to 5000Ω input and 5000 to 40,000Ω output. The higher values are generally obtained in degenerative circuits. The common emitter circuit exhibits maximum voltage and power gain of the 3 basic configurations. There is phase reversal in this circuit and therefore the output signal is 180° out of phase with the input. Common Emitter circuits should generally be used with some form of bias stabilization. See Circuits 4, 6, 7, 8, 9, 10, 11.

4.2.1.1 Basic Circuit.

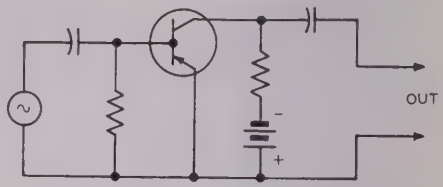
There are numerous variations on the basic amplifier shown as Circuit 1 and each modification to accomplish an end result will be discussed as we proceed. Circuit 1 is customarily referred to as "floating base" since no d-c bias is applied and the base floats at the static level of the very small



CIRCUIT 1

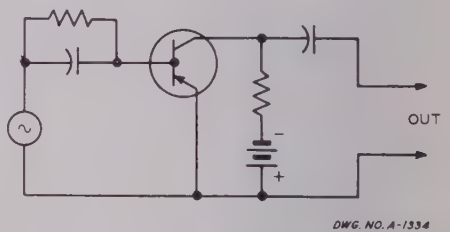
drop across the emitter resistance. This arrangement is quite temperature sensitive and this must be taken into account in equipment design.

4.2.1.2 To reduce battery current consumption, a small current must flow out of the base. This is easily accomplished by the addition of another resistor as shown in Circuit 2. This circuit is also temperature sensitive.



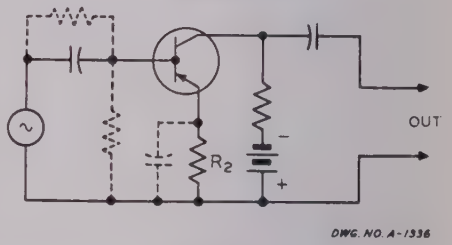
CIRCUIT 2

4.2.1.3 Circuit 3 may be considered as an alternate to Circuit 2. However in Circuit 3 the signal source must have a relatively low d-c resistance and no d-c voltage impressed across it.



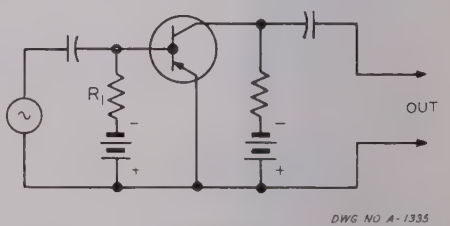
CIRCUIT 3

4.2.1.4 The collector current obtained in Circuits 2 and 3 may be decreased still further by the addition of a resistor in series with the emitter and ground as shown in Circuit 4. While Resistor R_2 reduces collector current, it introduces degeneration. It does, however, provide a small degree of stabilization. If degeneration is not desired, R_2 may be bypassed for the frequency range involved. Thus gain may be maintained while taking advantage of reduced collector current and of stabilization.



CIRCUIT 4

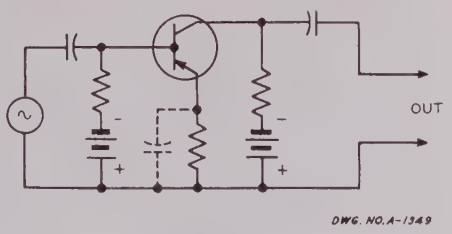
4.2.1.5 To increase collector current, a fixed d-c bias voltage must be provided for the base. Circuit 5 shows such connection using a separate supply for the base bias. To stabilize the d-c bias operating point of Circuit 5, one may employ three different techniques or they may be used in combination. The three basic methods are, of course, Emitter Degeneration, Voltage Divider, and Base-Collector Bias Stabilization.



CIRCUIT 5

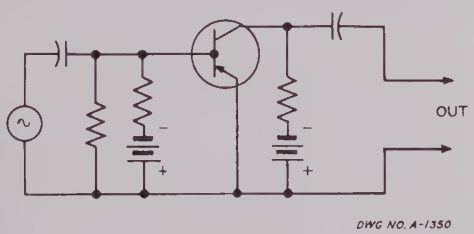
4.2.1.6 Circuit 6 shows how the previous circuit is modified by turning on the Emitter Degeneration Control, introducing a resistance of up to 2,500Ω in series with the emitter. If used without a bypass capacitor,

this will result in signal degeneration. Should this be objectionable, a capacitor of proper value should be connected across the terminals which have been provided for it. The introduction of resistance in the emitter circuit will result in an increase of impedance as well as stabilization of the operating bias. The amount of resistance introduced will determine the degree of stabilization and the value finally selected will take into account the impedance, the degeneration, and the stabilization required.

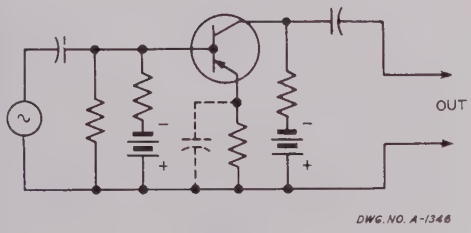


CIRCUIT 6

4.2.1.7 Circuit 7 shows how Circuit 5 is modified by turning on the Voltage Divider Stabilization Control. Note that this variable resistor is connected so that the full 50,000Ω is in the circuit as soon as the control is switched in. In use, this control and Input Resistors 1, 2, and 3 are slowly adjusted to the lowest value useable, which is consistent with the available circuit current. However, keep the Voltage Divider Stabilization Control to as low a value as is possible without undue signal loss. Note that the Voltage Divider Stabilization Control is in shunt with the input signal and reducing its value to zero would short both base and input signal to ground.



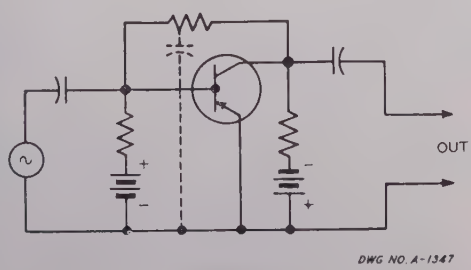
CIRCUIT 7



CIRCUIT 8

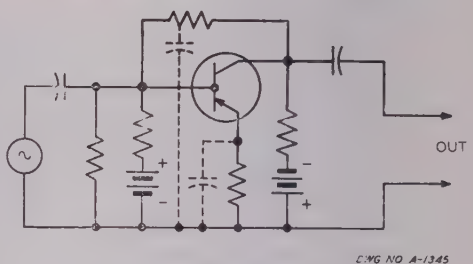
4.2.1.8 A combination of the Emitter Degeneration and Voltage Divider methods of bias stabilization are shown in Circuit 8.

4.2.1.9 In Circuit 9 is shown the modification of Circuit 5 for Base-Collector Stabilization. Note that the maximum value of 250,000Ω is in the circuit as soon as the B-C Stabilization Control is turned on. The use of this control introduces degenerative signal feedback which may be reduced by the modifications shown in Circuit 11. It should also be noted that the output polarity selector may sometimes be set to the + position instead of to — as shown in the table on page 2 so that the positive bias will offset the negative feedback from the collector.



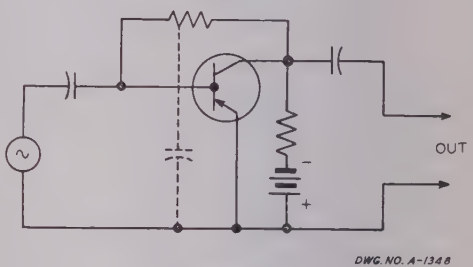
CIRCUIT 9

4.2.1.10 A combination of all three methods of Stabilization Control is shown in Circuit 10. Here Emitter Degeneration, Voltage Divider, and Base-Collector Stabilization are all utilized at one time.



CIRCUIT 10

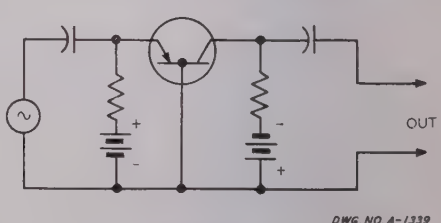
4.2.1.11 Sometimes it is desirable to omit the fixed input bias source from the Base-Collector Stabilization method (Circuit 9). The drawing of Circuit 11 shows how this is done. This connection results in stabilization of the d-c bias operating point of the transistor although it does result in signal degeneration. The stabilization may be small in the case of a low value collector load resistance but it may be quite large if the load resistance is high. Should the degeneration be undesirable, it may be eliminated from the feedback loop by using a bypass capacitor of suitable value across the terminals provided for it on the LF-1, removing the link from the B-C Stabilization Resistor terminals and connecting to them a resistor equal to $\frac{1}{2}$ the value of the desired collector-base feedback resistance, and adjusting the B-C Stabilization Control to furnish the other $\frac{1}{2}$ of the desired resistance. If the collector load impedance is low, the amount of degeneration will be small. In this case, the feedback resistor will not usually be bypassed.



CIRCUIT 11

4.2.2 Grounded Base. Grounded base circuits exhibit low input impedance and high output impedance. They are usually employed for impedance matching. Moderate power and voltage gain is achieved. There is no phase shift, so that the output signal is in phase with the input. As these circuits are fully degenerative, no stabilization is usually required.

4.2.2.1 Basic Circuit. A typical grounded base circuit is shown in the drawing of Circuit 12.

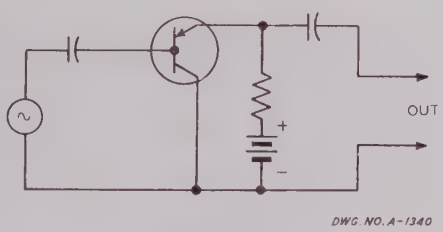


CIRCUIT 12

4.2.3 Grounded Collector. Grounded collector circuits are similar to electron-tube cathode-follower circuits. They are usually used for similar purposes in converting from a high input to a low output impedance. The value of the impedances, input and output, is dependent on the characteristics of a particular transistor and the input and output circuit currents. Generally, lower currents result in higher impedances. The voltage gain of the common collector circuit is less than unity but a small power gain is obtained. There is no phase shift in this circuit and therefore the out-

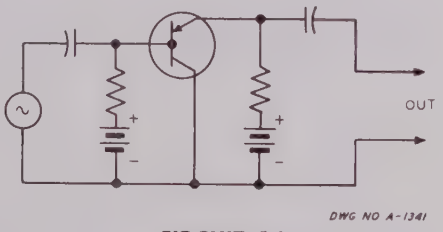
put signal is in phase with the input signal. No stabilization is usually required.

4.2.3.1 Basic Circuit. In Circuit 13 is shown a high impedance input grounded collector circuit.



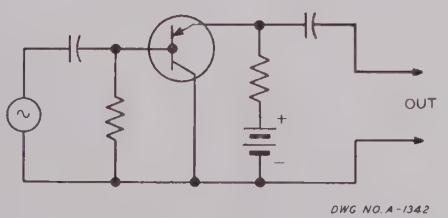
CIRCUIT 13

4.2.3.2 The circuit may be modified by the introduction of base bias voltage as shown in Circuit 14 in order to lower the collector current. Note, however, that the voltage applied to the base and the series resistance will determine whether the collector current will decrease or increase.



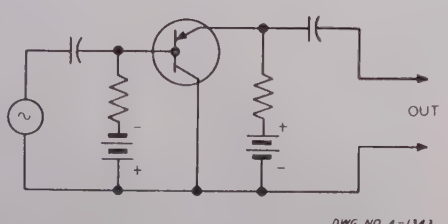
CIRCUIT 14

4.2.3.3 Where higher collector current is desired, Circuit 15 is often used. This omits the fixed input bias from the previous drawing.



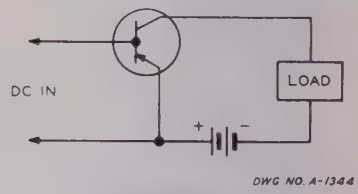
CIRCUIT 15

4.2.3.4 Another way to obtain higher collector current is by reversing the input voltage polarity of Circuit 14. The resultant circuit is shown in Circuit 16. *Be very cautious* in using this circuit! Use the minimum base-bias voltage and maintain a high resistance setting on the input controls R_1, R_2, and R_3 which is consistent with the emitter current desired. *Failure to observe these precautions may result in destruction of the transistor.*



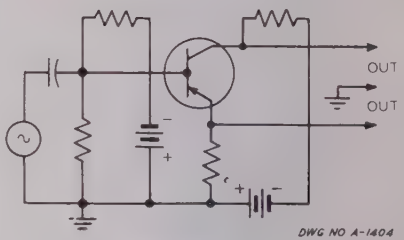
CIRCUIT 16

4.2.4 Grounded Emitter as a D-C Amplifier. Circuit 17 shows the use of the grounded emitter configuration as a d-c amplifier circuit.



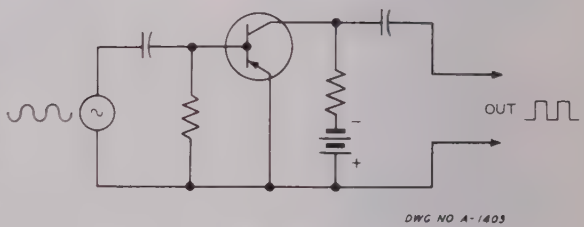
CIRCUIT 17

4.2.5 Phase Inverter. The use of a transistor as a phase inverter is shown in the drawing of Circuit 18.



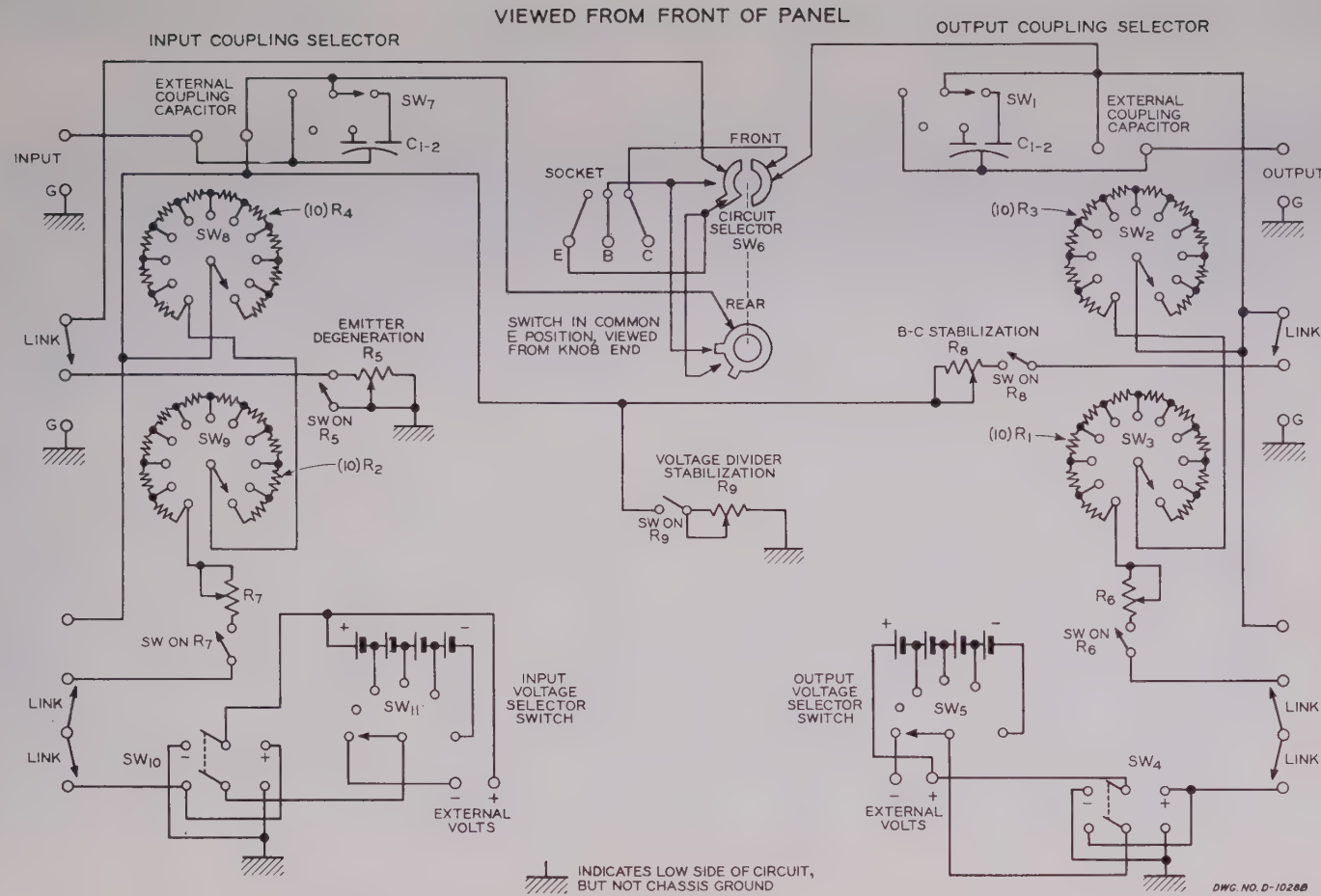
CIRCUIT 18

4.2.6 Square Wave Generator. Circuit 19 shows a sine-wave clipper. This over-driven amplifier has a square wave output.



CIRCUIT 19

USER'S NOTES


VIEWED FROM FRONT OF PANEL
INPUT COUPLING SELECTOR
OUTPUT COUPLING SELECTOR
EXTERNAL COUPLING CAPACITOR
SW7
C1-2
INPUT
G
SW8
(10) R4
LINK
EMITTER DEGENERATION R5
SW ON R5
SW9
(10) R2
R7
SW ON R7
LINK
LINK
SW10
SW11
INPUT VOLTAGE SELECTOR SWITCH
EXTERNAL VOLTS
SOCKET
FRONT
CIRCUIT SELECTOR SW6
REAR
E
B
C
SWITCH IN COMMON E POSITION, VIEWED FROM KNOB END
VOLTAGE DIVIDER STABILIZATION R9
SW ON R9
SW1
C1-2
EXTERNAL COUPLING CAPACITOR
OUTPUT
G
(10) R3
SW2
LINK
B-C STABILIZATION R8
SW ON R8
G
(10) R1
SW3
R6
SW ON R6
LINK
LINK
OUTPUT VOLTAGE SELECTOR SWITCH
SW5
SW4
EXTERNAL VOLTS
INDICATES LOW SIDE OF CIRCUIT, BUT NOT CHASSIS GROUND
DWG. NO. D-1028B

5. QUICK CIRCUIT SET-UP MODEL LF-1

5.1 Always Set Controls to Normal Position for Internal Operation and have terminal connections at normal before starting Set-up.

Control or Terminals		Normal	Circuit 1	
Description	Ref. No.	Control Pos. or Terminal Conn.	Control Pos. or Term. Conn.	Step
Input Voltage Selector	3.1	Off	Off	
Input External Volts Terminals	3.2	Open	Open	
Output Voltage Selector	3.3	Off	Set to Value	8
Output External Volts Terminals	3.4	Open	Open	
Input Resistor 1 (See Note 7)	3.5	Max. Ω	Max. Ω	
Input Resistor 2 (See Note 7)	3.6	Max. Ω	Max. Ω	
Input Resistor 3 (See Note 7)	3.7	Max. Ω	Max. Ω	
Input Meter Terminals	3.8	Link or Meter	Link or Meter	
Input Series Resistor Terminals	3.9	Link	Link	
Input External Load Terminals	3.10	Open	Open	
Emitter Degeneration Control	3.11	Off	Off	
Emitter Degeneration Capacitor Terminals	3.12	Open	Open	
Emitter Degeneration Resistor Terminals	3.13	Link	Link	
Voltage Div. Stabilization Control	3.14	Off	Off	
B-C Stabilization Control	3.15	Off	Off	
B-C Stabilization Capacitor Terminals	3.16	Open	Open	
B-C Stabilization Resistor Terminals	3.17	Link	Link	
Output Resistor 1 (See Note 8)	3.18	Max. Ω	Adjust	9
Output Resistor 2 (See Note 8)	3.19	Max. Ω	Adjust	10
Output Resistor 3 (See Note 8)	3.20	Max. Ω	Adjust	11
Output Meter Terminals	3.21	Link or Meter	Link or Meter	
Output Series Resistor Terminals	3.22	Link	Link	
Output External Load Terminals	3.23	Open	Open	
Input Voltage Polarity Selector	3.24	+ or —	+ or —	
Output Voltage Polarity Selector	3.25	+ or —	—	6
Input Signal Terminals	3.26	Open	Connect Signal	2
Input External Coupling Cap. Terminals	3.27	Open	Open	
Input Coupling Selector	3.28	2, 20, or EXT.	2 or 20	3
Circuit Selector	3.29	E, B, or C	E	7
Transistor Socket	3.30	Open	Plug-in	
Transistor Terminals	3.31	Open	or Connect Transistor	1
Output Signal Terminals	3.32	Open	Connect Signal Out	5
Output External Coupling Cap. Terminals	3.33	Open	Open	
Output Coupling Selector	3.34	2, 20, or EXT.	2 or 20	4

For Notes, see Page 23.

HART FOR SPRAGUE RANSIMULATOR

5.2 Follow numbered step-by-step procedure to set-up each circuit on the Transimulator.

Circuit 2		Circuit 3		Circuit 4		Circuit 5		Circuit 6	
Control Pos. Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step
Off		Off		Off		Set to Value	9	Set to Value	9
Open		Open		Open		Open		Open	
et to Value	10	Set to Value	10	Set to Value	10	Set to Value	10	Set to Value	10
Open		Open		Open		Open		Open	
Adjust	11	Adjust	11	Adjust	11	Adjust	11	Adjust	11
Adjust	12	Adjust	12	Adjust	12	Adjust	12	Adjust	12
Adjust	13	Adjust	13	Adjust	13	Adjust	13	Adjust	13
nk or Meter Link		Link or Meter Link		Link or Meter Link		Link or Meter Link		Link or Meter Link	
Open See Note 1	8	Open See Note 2	8	Open See Note 3	9	Open		Open	
Off		Off		Adjust	17	Off		Adjust	17
Open See Note 1	9	Open		Open See Note 3 See Note 4	8 18	Open		Open See Note 4	18
Link		Link		Link See Note 5	19	Link		Link See Note 5	19
Off		Off		Off		Off		Off	
Off		Off		Off		Off		Off	
Open		Open		Open		Open		Open	
Link		Link		Link		Link		Link	
Adjust	14	Adjust	14	Adjust	14	Adjust	14	Adjust	14
Adjust	15	Adjust	15	Adjust	15	Adjust	15	Adjust	15
Adjust	16	Adjust	16	Adjust	16	Adjust	16	Adjust	16
nk or Meter Link		Link or Meter Link		Link or Meter Link		Link or Meter Link		Link or Meter Link	
Open		Open		Open		Open		Open	
+ or —		+ or —		+ or —		—	7	—	7
—	6	—	6	—	6	—	6	—	6
onnect Signal	2	Connect Signal	2	Connect Signal	2	Connect Signal	2	Connect Signal	2
Open		Open See Note 2	9	Open See Note 3	8A	Open		Open	
2 or 20	3	2 or 20	3	2 or 20	3	2 or 20	3	2 or 20	3
E	7	E	7	E	7	E	8	E	8
lug in r Connect ransistor	1	Plug in or Connect Transistor	1	Plug in or Connect Transistor	1	Plug in or Connect Transistor	1	Plug in or Connect Transistor	1
Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5
Open		Open		Open		Open		Open	
2 or 20	4	2 or 20	4	2 or 20	4	2 or 20	4	2 or 20	4

r Notes, see page 23.

Control or Terminals		Normal Control Pos. or Terminal Conn.	Circuit 7	
Description	Ref. No.		Control Pos. or Term. Conn.	Step
Input Voltage Selector	3.1	Off	Set to Value	9
Input External Volts Terminals	3.2	Open	Open	
Output Voltage Selector	3.3	Off	Set to Value	10
Output External Volts Terminals	3.4	Open	Open	
Input Resistor 1	3.5	Max. Ω	Adjust	11
Input Resistor 2 (See Note 7)	3.6	Max. Ω	Adjust	12
Input Resistor 3	3.7	Max. Ω	Adjust	13
Input Meter Terminals	3.8	Link or Meter	Link or Meter	
Input Series Resistor Terminals	3.9	Link	Link	
Input External Load Terminals	3.10	Open	Open	
Emitter Degeneration Control	3.11	Off	Off	
Emitter Degeneration Capacitor Terminals	3.12	Open	Open	
Emitter Degeneration Resistor Terminals	3.13	Link	Link	
Voltage Div. Stabilization Control	3.14	Off	Adjust	17
B-C Stabilization Control	3.15	Off	Off	
B-C Stabilization Capacitor Terminals	3.16	Open	Open	
B-C Stabilization Resistor Terminals	3.17	Link	Link	
Output Resistor 1	3.18	Max. Ω	Adjust	14
Output Resistor 2 (See Note 8)	3.19	Max. Ω	Adjust	15
Output Resistor 3	3.20	Max. Ω	Adjust	16
Output Meter Terminals	3.21	Link or Meter	Link or Meter	
Output Series Resistor Terminals	3.22	Link	Link	
Output External Load Terminals	3.23	Open	Open	
Input Voltage Polarity Selector	3.24	+ or —	—	7
Output Voltage Polarity Selector	3.25	+ or —	—	6
Input Signal Terminals	3.26	Open	Connect Signal	2
Input External Coupling Cap. Terminals	3.27	Open	Open	
Input Coupling Selector	3.28	2, 20, or EXT.	2 or 20	3
Circuit Selector	3.29	E, B, or C	E	8
Transistor Socket	3.30	Open	Plug In or Connect Transistor	1
Transistor Terminals	3.31	Open		
Output Signal Terminals	3.32	Open	Connect Signal Out	5
Output External Coupling Cap. Terminals	3.33	Open	Open	
Output Coupling Selector	3.34	2, 20, or EXT.	2 or 20	4

For Notes, see Page 23.

Circuit 8		Circuit 9		Circuit 10		Circuit 11		Circuit 12	
ntrol Pos. or erm. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step
t to Value	9	Set to Value	9	Set to Value	9	Off		Set to Value	9
Open		Open		Open		Open		Open	
t to Value	10	Set to Value	10	Set to Value	10	Set to Value	8	Set to Value	10
Open		Open		Open		Open		Open	
Adjust	11	Adjust	11	Adjust	11	Max. Ω		Adjust	11
Adjust	12	Adjust	12	Adjust	12	Max. Ω		Adjust	12
Adjust	13	Adjust	13	Adjust	13	Max. Ω		Adjust	13
nk or Meter		Link or Meter		Link or Meter		Link or Meter		Link or Meter	
Link		Link		Link		Link		Link	
Open		Open		Open		Open		Open	
Adjust	18	Off		Adjust	17	Off		Off	
Open See Note 4	19	Open		Open See Note 4	18	Open		Open	
Link See Note 5	20	Link		Link See Note 5	19	Link		Link	
Adjust	17	Off		Adjust	20	Off		Off	
Off		Adjust	11	Adjust	11	Adjust	9	Off	
Open		Open See Note 6	17	Open See Note 6	21	Open See Note 6	13	Open	
Link		Link See Note 6	18	Link See Note 6	22	Link See Note 6	14	Link	
Adjust	14	Adjust	14	Adjust	14	Adjust	10	Adjust	14
Adjust	15	Adjust	15	Adjust	15	Adjust	11	Adjust	15
Adjust	16	Adjust	16	Adjust	16	Adjust	12	Adjust	16
nk or Meter		Link or Meter		Link or Meter		Link or Meter		Link or Meter	
Link		Link		Link		Link		Link	
Open		Open		Open		Open		Open	
—	7	+	7	+	7	+ or —		+	7
—	6	—	6	—	6	—	6	—	6
onnect Signal	2	Connect Signal	2	Connect Signal	2	Connect Signal	2	Connect Signal	2
Open		Open		Open		Open		Open	
2 or 20	3	2 or 20	3	2 or 20	3	2 or 20	3	2 or 20	3
E	8	E	8	E	8	E	7	B	8
ug In Connect ransistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1
Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5
Open		Open		Open		Open		Open	
2 or 20	4	2 or 20	4	2 or 20	4	2 or 20	4	2 or 20	4

Control or Terminals		Normal Control Pos. or Terminal Conn.	Circuit 13	
Description	Ref. No.		Control. Pos. or Term. Conn.	Step
Input Voltage Selector	3.1	Off	Off	
Input External Volts Terminals	3.2	Open	Open	
Output Voltage Selector	3.3	Off	Set to Value	8
Output External Volts Terminals	3.4	Open	Open	
Input Resistor 1 (See Note 7)	3.5	Max. Ω	Max. Ω	
Input Resistor 2 (See Note 7)	3.6	Max. Ω	Max. Ω	
Input Resistor 3 (See Note 7)	3.7	Max. Ω	Max. Ω	
Input Meter Terminals	3.8	Link or Meter	Link or Meter	
Input Series Resistor Terminals	3.9	Link	Link	
Input External Load Terminals	3.10	Open	Open	
Emitter Degeneration Control	3.11	Off	Off	
Emitter Degeneration Capacitor Terminals	3.12	Open	Open	
Emitter Degeneration Resistor Terminals	3.13	Link	Link	
Voltage Div. Stabilization Control	3.14	Off	Off	
B-C Stabilization Control	3.15	Off	Off	
B-C Stabilization Capacitor Terminals	3.16	Open	Open	
B-C Stabilization Resistor Terminals	3.17	Link	Link	
Output Resistor 1 (See Note 8)	3.18	Max. Ω	Adjust	9
Output Resistor 2 (See Note 8)	3.19	Max. Ω	Adjust	10
Output Resistor 3 (See Note 8)	3.20	Max. Ω	Adjust	11
Output Meter Terminals	3.21	Link or Meter	Link or Meter	
Output Series Resistor Terminals	3.22	Link	Link	
Output External Load Terminals	3.23	Open	Open	
Input Voltage Polarity Selector	3.24	+ or —	+ or —	
Output Voltage Polarity Selector	3.25	+ or —	+	6
Input Signal Terminals	3.26	Open	Connect Signal	2
Input External Coupling Cap. Terminals	3.27	Open	Open	
Input Coupling Selector	3.28	2, 20, or EXT.	2 or 20	3
Circuit Selector	3.29	E, B, or C	C	7
Transistor Socket	3.30	Open	Plug In or Connect Transistor	1
Transistor Terminals	3.31	Open		
Output Signal Terminals	3.32	Open	Connect Signal Out	5
Output External Coupling Cap. Terminals	3.33	Open	Open	
Output Coupling Selector	3.34	2, 20, or EXT.	2 or 20	4

Circuit 14		Circuit 15		Circuit 16		Circuit 17		Circuit 18	
Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step	Control Pos. or Term. Conn.	Step
Set to Value	9	Off		Set to Value	9	Off		Set to Value	8
Open		Open		Open		Open		Open	
Set to Value	10	Set to Value	10	Set to Value	10	Set to Value	7	Set to Value	9
Open		Open		Open		Open		Open	
Adjust	11	Max. Ω	11	Adjust	11	Max. Ω		Adjust	10
Adjust	12	Max. Ω	12	Adjust	12	Max. Ω		Adjust	11
Adjust	13	Max. Ω	13	Adjust	13	Max. Ω		Adjust	12
Link or Meter		Link or Meter		Link or Meter		Link or Meter		Link or Meter	
Link		Link		Link		Link		Link	
Open		Open See Note 1	8	Open		Open		Open	
Off		Off		Off		Off		Adjust See Notes 9, 10, and 11	17
Open		Open See Note 1	9	Open		Open		Open	
Link		Link		Link		Link		Link See Note 5	16
Off		Off		Off		Off		Adjust	18
Off		Off		Off		Off		Off	
Open		Open		Open		Open		Open	
Link		Link		Link		Link		Link	
								See Note 11	
Adjust	14	Adjust	14	Adjust	14	Max. Ω		Adjust	13
Adjust	15	Adjust	15	Adjust	15	Max. Ω		Adjust	14
Adjust	16	Adjust	16	Adjust	16	Off	8	Adjust	15
Link or Meter		Link or Meter		Link or Meter		Link or Meter		Link or Meter	
Link		Link		Link		Link		Link	
Open		Open		Open		Ext. Load	4	Open	
+	7	+ or —		—	7	+ or —		—	6
+	6	+	6	+	6	—	5	—	5
Connect Signal	2	Connect Signal	2	Connect Signal	2	Connect Signal	6	Connect Signal	7
Open		Open		Open		Open		Open	
2 or 20	3	2 or 20	3	2 or 20	3	Direct	3	2 or 20	
C	8	C	7	C	8	E	2	E	
Plug In or Connect Transistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1	Plug In or Connect Transistor	1
Connect Signal Out	5	Connect Signal Out	5	Connect Signal Out	5	Open		Connect Signal Out	2
Open		Open		Open		Open		Open	4
2 or 20	4	2 or 20	4	2 or 20	4	2 or 20		See Note 10	3

Control or Terminals		Normal	Circuit 19	
Description	Ref. No.	Control Pos. or Terminal Conn.	Control Pos. or Term. Conn.	Step
Input Voltage Selector	3.1	Off	Off	
Input External Volts Terminals	3.2	Open	Open	
Output Voltage Selector	3.3	Off	Set to Value	10
Output External Volts Terminals	3.4	Open	Open	
Input Resistor 1 (See Note 7)	3.5	Max. Ω	Adjust	11
Input Resistor 2 (See Note 7)	3.6	Max. Ω	Adjust	12
Input Resistor 3 (See Note 7)	3.7	Max. Ω	Adjust	13
Input Meter Terminals	3.8	Link or Meter	Link or Meter	
Input Series Resistor Terminals	3.9	Link	Link	
Input External Load Terminals	3.10	Open	See Note 1 / Open	8
Emitter Degeneration Control	3.11	Off	Off	
Emitter Degeneration Capacitor Terminals	3.12	Open	Open / See Note 1	9
Emitter Degeneration Resistor Terminals	3.13	Link	Link	
Voltage Div. Stabilization Control	3.14	Off	Off	
B-C Stabilization Control	3.15	Off	Off	
B-C Stabilization Capacitor Terminals	3.16	Open	Open	
B-C Stabilization Resistor Terminals	3.17	Link	Link	
Output Resistor 1 (See Note 8)	3.18	Max. Ω	Adjust	14
Output Resistor 2 (See Note 8)	3.19	Max. Ω	Adjust	15
Output Resistor 3 (See Note 8)	3.20	Max. Ω	Adjust	16
Output Meter Terminals	3.21	Link or Meter	Link or Meter	
Output Series Resistor Terminals	3.22	Link	Link	
Output External Load Terminals	3.23	Open	Open	
Input Voltage Polarity Selector	3.24	+ or —	+ or —	
Output Voltage Polarity Selector	3.25	+ or —	—	6
Input Signal Terminals	3.26	Open	Connect Signal	2
Input External Coupling Cap. Terminals	3.27	Open	Open	
Input Coupling Selector	3.28	2, 20, or EXT.	2 or 20	3
Circuit Selector	3.29	E, B, or C	E	7
Transistor Socket	3.30	Open	Plug In or Connect Transistor	1
Transistor Terminals	3.31	Open		
Output Signal Terminals	3.32	Open	Connect Signal Out	5
Output External Coupling Cap. Terminals	3.33	Open	Open	4
Output Coupling Selector	3.34	2, 20, or EXT.	2 or 20	3

For Notes, see Page 23.

5.3 Notes

Note 1: Connect jumper from bottom Emitter Degeneration Capacitor Terminal to bottom Input External Load Terminal.

Note 2: Connect jumper from bottom Input External Load Terminal to left terminal, Input External Coupling Capacitor.

Note 3: Connect in accordance with Notes 1 or 2, depending on the circuit which you wish to use.

Note 4: Connect a suitable bypass capacitor across the Emitter Degeneration Capacitor Terminals, if desired.

Note 5: If it is necessary to increase the value of the emitter degeneration resistance beyond 2500 ohms, remove the link and connect the padding resistor across the Emitter Degeneration Resistor Terminals.

Note 6: To eliminate degeneration in the feedback loop, connect a suitable bypass capacitor across the B-C Stabilization Capacitor Terminals. At the same time, open the link across the B-C Stabilization Resistor Terminals and substitute a resistor equal to $\frac{1}{2}$ the value of the total feedback resistance. The total value of resistance is first determined by adjustment of the B-C Stabilization Control for proper base d-c bias. Adjust the B-C Stabilization Control to the same value of resistance as the selected resistor to complete the loop.

Note 7: Input Resistors 1, 2, and 3 are always set at maximum and adjusted toward minimum when using these controls.

Note 8: Output Resistors 1, 2, and 3 are always set at maximum and adjusted toward minimum when using these controls.

When both Input and Output Resistors are used, their adjustments are coordinated to produce proper circuit operation.

Note 9: Output is taken from the center Emitter Degeneration Terminal unless an external resistor is connected in the circuit. In this case, take the output from the top binding post. A coupling capacitor of choice may be connected in series with either terminal, to couple the output signal to the following stage.

Note 10: When using a coupling capacitor in accordance with Note 9, the Output Coupling Selector may be set on EXT. CAP. position and a matching capacitor connected across the output external coupling capacitor terminals so that the second output signal may be taken from the Output Signal Terminals as usual.

Note 11: The collector and emitter resistance values may not be equal for equal signal output.

6. Transformer-Coupled Circuits

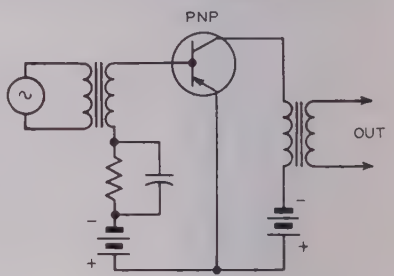
6.1 The circuits discussed previously have been of the R-C or direct-coupled type. In some cases, transformer coupling is advantageous.

6.2 The use of the primary of an output transformer or other load impedance in the output circuit is usually very easily accomplished by setting Output Resistor 3 to OFF and connecting across the Output External Load terminals. Voltage from the supply is thus fed to the output element of the transistor through the transformer or impedance.

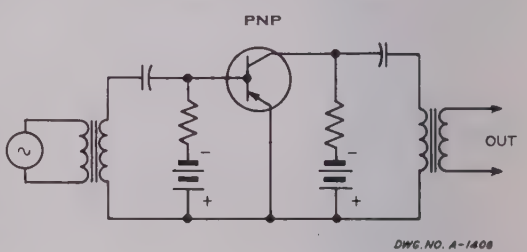
6.3 However, the introduction of the signal into the input circuit must be accomplished in such a manner as to maintain the d-c requirements of the bias circuit. The secondary of an interstage coupling trans-

former is connected to the External Load terminals on the input side of the panel and Input Resistor 3 is set to OFF position. Thus the signal is introduced into the input circuit, and in some cases the d-c resistance of the transformer may serve as the bias resistance, but more likely, the d-c resistance is not high enough. Therefore, it is necessary to introduce additional resistance in series with the transformer winding to provide proper element bias. Generally, this resistance must be bypassed for a-c to prevent signal loss. The required resistance shunted by the required capacitance is connected across the Input Series Resistor Terminals after first removing the link normally across these terminals. This results in the bypassed resistance being connected in series with the transformer, and proper voltage being applied to the input transistor element.

6.4 The above represents series introduction of signal into the input and take-off of signal from the output circuits. See circuit at the right. It should be noted that the standard procedure as established for R-C circuits may be used to introduce Emitter Degeneration Bias Stabilization, B-C Stabilization, Voltage Divider stabilization etc. into this basic circuit.



6.5 Sometimes it may be desired to transformer couple the circuit input or output with no d-c carried by the transformer winding. In this case, the basic R-C circuit would be used with the signal in supplied by the secondary of a transformer applied across the regular Signal Input terminals, and signal taken out by the primary of a transformer connected across the regular Signal Output terminals. Input and output coupling capacitors would be used, and the d-c voltages applied to the transistor elements would be undisturbed. Such transformer connections would constitute shunt feed transformer coupling. See circuit at the right.



7. Multiple Stage Operation

7.1 The Transimulator as supplied is a single stage circuit. Since we seldom use single stage circuits alone, it is desirable to consider the instrument as a variable stage moved stage by stage from input to output.

7.2 Let us consider, as an example, a three-stage cascade audio amplifier, and designate values of elements associated with each stage. The procedure for establishing each value for each stage is the same as the procedure for a single stage which will be found under the circuit set-up instructions in this manual.

7.2.1 Step 1 is to design the input stage using an input signal level approximating that expected in actual use. This signal may be an audio

generator set for whatever frequency desired, or 1000 cycles as a reference, or the actual signal producing device such as phono pickup, microphone, or r-f detector output. The output of this stage is observed using an oscilloscope, or an audio amplifier may be used to listen to the output. In either case, by proper operation of the LF-1 variable parameters, a point of maximum gain and minimum distortion will be located, with or without stabilization introduced by use of the appropriate controls. An oscilloscope or a-c vacuum-tube voltmeter is most useful for determining the value of the output signal level as a reference level for the input of the next stage, and an audio signal generator is desirable for producing the desired level for each following stage. A resistor approximating input impedance of the next stage should be connected across the output signal terminals (Ref. 3.32) for final voltage measurement; or, if a transformer is used, the secondary should be connected across a resistance equal to the input impedance of the next stage or the rated impedance of the transformer secondary. At this point, the input stage circuit may be wired using parts values determined by the Transimulator, and the actual working stage used for output to the input of the second stage.

7.2.2 Step 2 is the design of the second stage using standard LF-1 procedure and as per Step 1.

7.2.3 Step 3 is the design of the output stage using the output level of the second stage as an input reference for the output stage. Usually the output stage uses the primary of an output transformer, or phones etc. for a load which is connected to the Output External Load terminals.

7.3 As will be noted, no reference was made above to the type of circuit, stage by stage, as it is possible to set-up any combination, even direct-coupling stages if desired. For example, the input stage could be a common collector stage to match the high impedance of a ceramic phono cartridge, coupled to the second stage which could be a common base circuit to match the low impedance of the output of the common collector stage, followed by a common emitter stage with or without degeneration or emitter stabilization. The fact that these combinations can be accomplished shows the versatility of the Transimulator.

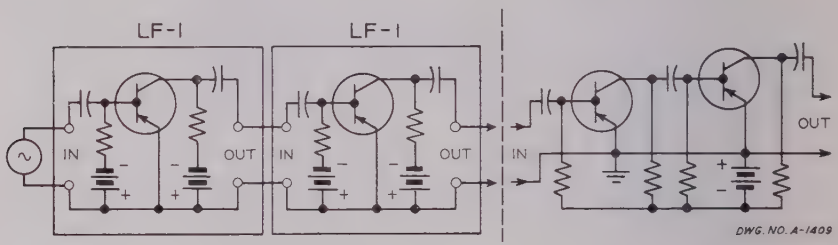
7.4 The stage-by-stage procedure may be greatly simplified by the use of a separate Transimulator for each stage so that the entire circuit may be set-up in working condition and performance determined as well as noting the effect of minor variations of each stage as affecting preceding or following stages. The Transimulator may be used in parallel for push-pull coupling or PNP-NPN symmetrical amplifiers or Class A, B, or AB output amplifiers, flip-flop or one shot multivibrators, and audio oscillators. The LF-1 may be used singly, or in cascade, or in parallel to design and make operative any stage using the inbuilt parameters or other parameters properly connected, to an upper frequency range determined by the shunt capacitances of the Instrument in relation to the impedance level of the desired stage operation.

7.5 Operating Notes.

7.5.1 Battery or Power Supply. As each LF-1 has two battery power supplies for powering the Input Circuit and Output Circuit with voltage of the amount and polarity desired, with, in each case, the opposite polarity of that supply returned to the common element as shown in the diagram, it should be noted that the power supplies of cascaded or parallel LF-1 units may be considered as one supply, which is usually desirable, or in rare instances as separate supplies if desired. When using a single source d-c supply, cascaded stages should be decoupled by conventional R-C networks to avoid regeneration. We will assume opera-

tion from a common supply as shown on the right hand side of the accompanying drawing. You will note that it is not necessary to use the same voltage level for Input and Output bias as the input may be biased at a low d-c level, such as a tap on the common supply. But if it is known that an untapped supply is to be used for both input and output biases, then the Input and Output voltage supplies are set to the same level, or supplied from the same external source. *In any case, a-c/d-c or direct line fed d-c supplies should never be used to power the Transimulator.*

7.5.1.1 If the instrument is not used for any great length of time, always check the internal dry batteries since battery potential changes with age and use of the batteries. It is also important to check the potential of the internal dry batteries before and during any intensive circuit set-up work so that results will not be misleading because of partially exhausted batteries.



7.5.2 Coupling Capacitors.

7.5.2.1 When using LF-1 units in cascade, it should be noted that the output coupling capacitor of the first stage is in series with the input capacitor of the second stage, etc. Whether the capacitors provided in the LF-1 or external coupling capacitors are being used, the resultant capacitance of the 2 capacitors may be calculated by the formula:

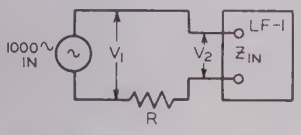
$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

Or either the Output circuit of the first stage or the Input circuit of the second stage may be set to *direct*, thus leaving only one capacitor as coupling between stages.

7.5.2.2 The LF-1 coupling capacitors are special non-polarized electrolytics with a 100 vdc rating which permits application of direct voltage of either polarity, making it unnecessary to observe polarity when cascading stages. However, the finished circuit will undoubtedly use polarized electrolytics, so that it is necessary that proper polarity be observed when connecting the circuit. The proper polarity may be determined either by inspection or measurement of the voltage on the output element of the first stage and the voltage on the input element of the second stage. *For example*, assume each circuit to be common emitter, and the voltage on the collector of the first stage measures −2 volts and the voltage on the base of the input stage measures −.2 volts, then the capacitor would be positioned with the negative terminal to the collector of the first stage and the positive terminal to the base of the second stage. The d-c voltage rating of the capacitor should be equal to the *supply* voltage to the collector circuit of the first stage plus the *supply* voltage to the input circuit of the second stage where the two supplies are of opposite polarity, and at least equal to the *supply* voltage to the collector or output circuit of the first stage, when they are of the same polarity. For commercial work, make certain to use transistor-type aluminum electrolytics. In military and

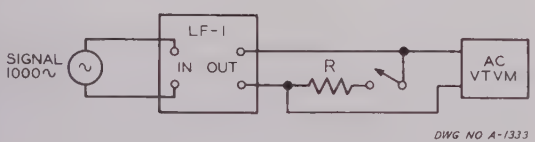
aircraft design, tantalum electrolytics are often required because of the wide ambient temperature variations.

7.5.2.3 The capacitance of the coupling capacitor chosen will depend on several factors, including the lowest frequency to be amplified and the circuit impedance. If possible, the capacitance chosen should have a reactance at the lowest frequency of not more than .1 of the input circuit impedance or output circuit impedance whichever is lower. The input circuit impedance may be found by using the test set-up and formula given below: LF-1 transistor circuit operating normally, and signal source in through a low impedance transformer secondary.



Because we are dealing with an actual working circuit in using the LF-1, the value of capacitor used may be chosen dynamically by observing the performance of the coupled circuits with various values of capacity either supplied internally by the LF-1 or connected to the External Capacitor terminals, observing proper polarity in the case of electrolytics.

7.5.3 The output impedance is usually relatively high matching into the input of the following transistor stage in the case of common emitter or base circuits and in R-C coupling the attendant mismatch loss is compensated, where necessary, by addition of another R-C stage. But in transformer coupling the output impedance must be known in order to select the proper interstage transformer impedance. The circuit arrangement for determining this impedance is shown in the drawing at the right.



With the LF-1 in operation and supplied with an input a-c signal, an a-c vacuum tube voltmeter is used to measure the open circuit a-c voltage across the output terminals of the LF-1. (The Output Selector switch is set at 20 μF for the entire operation.) Then with the meter still connected, a composition variable resistor R is connected across the LF-1 OUTPUT terminals and the value reduced until the a-c voltage read is $\frac{1}{2}$ that of the open circuit measurement. At this point, R may be removed and measured, and the resistance measured is equal to the output impedance of the LF-1 transistor amplifier circuit. Both the input and output impedance may be checked at frequencies other than 1000 cycles, consistent with the circuit being designed. At all times, if possible, an oscilloscope should be used to make sure the transistor amplifier is linear and not overdriven.

7.5.4 Power Transistors. Power transistors may be used in the LF-1, and the following procedure is suggested.

7.5.4.1 The power transistor may be connected to the EBC terminals provided on top of the LF-1 by means of clips or leads, making sure to effect connection to the proper transistor elements.

7.5.4.2 It is suggested that an external supply be provided to power the LF-1 because of the high drain of the power transistor.

7.5.4.3 The usual load for a power transistor is the primary of an output transformer, or the voice coil of the speaker, or a d-c relay coil, which is connected to the External Load terminals of the output circuit.

7.5.4.4 The base bias resistance is usually low in value. Input Resistor 3 may be used for values up to 5000 ohms at a maximum of $2\frac{1}{2}$ watts and not to exceed 1 watt at 1250 ohms, or either a fixed or variable low value resistance may be connected to the External Load terminals of the input circuit.

7.5.4.5 The emitter degeneration resistor, if used, will not exceed a few ohms and is best provided by connecting the resistor desired or a low range rheostat across the Emitter Degeneration Resistor terminals, first removing the link normally across these terminals. If a-c bypassing is desired to cancel the signal degeneration, the required capacitor may be connected in shunt with the low resistance across the Emitter Degeneration Resistor terminals.

7.5.4.6 By using two LF-1 units connected in parallel with the proper load and input signal, Class B operation of power transistors may be arranged and biases adjusted for proper cross-over operation.

7.5.5 Volume or Tone Control. In cascade circuit design, it is often desirable to provide volume control or tone compensation. The volume control or tone compensation circuit may be inserted between two stages of a cascade circuit, using two or more LF-1 units in series. There are many schemes for effecting this control, and the flexibility of the Transimulator will permit you to set up and determine the function of the circuit of your choice in conjunction with an operative circuit provided by the Instrument.

7.6 Grounding of Case. While the metal Transimulator case is insulated from the common or "ground" of the circuit, it may, in some instances, be desirable to attach an "earth" ground to the cabinet or even connect the "earth" ground to the circuit common (on the terminals marked G), especially if interference pickup proves to be a problem while working with low-level amplifier stages or in an electrically noisy area.

7.7 Additional Circuit Information. This instruction manual is not intended as a text book on transistors and transistor circuitry. There are many good books presently available on this subject and it is recommended that workers in the transistor field purchase such books in addition to reading the current trade magazines on developments in transistors and transistor circuitry.

8. Measuring Transistor Parameters

8.1 The Transimulator may be used for measuring the Alpha (a) and Beta (B) gain parameters of transistors, as detailed below.

8.1.1 The accuracy of the measurements will depend on the accuracy of the indicating meters used and of the care taken in making meter readings.

8.1.1.2 For Alpha measurements where the currents measured may differ by only 2% or less, it is imperative that the meters used for Emitter and Collector current measurements be calibrated against each other over the range of currents to be measured. If only one meter is available, first measure Emitter current and then substitute a resistor of *exact* d-c value equal to meter resistance before measuring collector current.

8.1.1.3 For Beta measurements, because of the difference in ranges required, of base current and collector current, it is important that each of the meters used be as accurate as possible, checked against a standard, and calibrated for deviations.

8.2 Alpha Measurement. For Alpha measurement at d-c, follow the procedure outlined below.

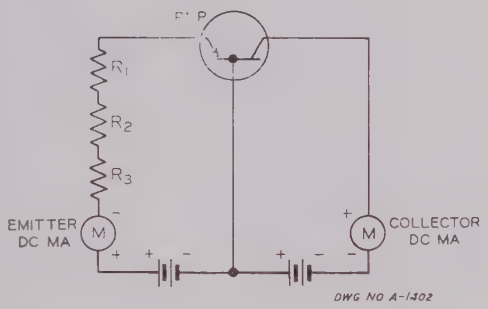
8.2.1 Set Circuit Selector to Common B.

8.2.2 Set Input Resistor 1, Resistor 2, and Resistor 3 to maximum resistance.

8.2.3 Remove link and connect a low range milliammeter between the Input Meter terminals with the + lead to the bottom post.

8.2.4 Set Input Polarity slide switch to +.

8.2.5 Set Output Resistor 3 to OFF.



8.2.6 Remove link and connect low range milliammeter between the output meter posts with the — lead to the bottom post.

8.2.7 Set Output Polarity slide switch to —.

8.2.8 Connect a shunt between binding posts marked EXTERNAL LOAD.

8.2.9 Insert transistor to be tested.

8.2.10 Select the Emitter current value at which you wish to run the test either from data sheets or choice. Decrease value of Input Resistor 1, Resistor 2, and Resistor 3 respectively until this adjustment with voltage selected by Input Voltage Selector produces the desired current...and at the same time set Output Voltage Selector to desired collector voltage.

8.2.11 Set the Emitter current to .1 ma lower than the selected value, by adjusting Input Resistor 1, Resistor 2, and Resistor 3, and read value on meter connected in step 8.2.3.

8.2.12 Record collector current read on meter connected in step 8.2.6, as I_{c_1}, at the emitter current obtained in Step 8.2.11.

8.2.13 Set the emitter current to .1 ma. higher than the selected value, by procedure of step 8.2.11.

8.2.14 Record collector current read on meter connected in step 6, as I_{c_2}, at the emitter current obtained in Step 8.2.13.

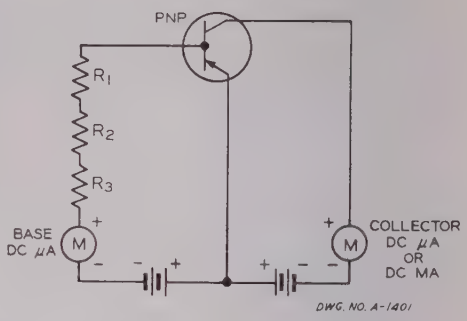
8.2.15 Subtract I_{c_1} from I_{c_2} and divide the difference by .2 ma or the net change in emitter current.

8.2.16 The result will be a decimal less than 1 for junction and surface barrier transistors, and is Alpha (α).

8.2.17 The procedure of steps 8.2.10 through 8.2.16 may be repeated for various levels of emitter current, to check variations in Alpha at different current levels.

8.2.18 During the above tests, all other elements of the Transimulator not used in steps above, are maintained in normal position.

8.3 Beta Measurement. For measurement of Beta of a transistor, set up the Transimulator as follows:



8.3.1 Set Circuit Selector to Common E.

8.3.2 Set Input Resistor 1, Resistor 2, and Resistor 3 to maximum resistance.

8.3.3 Remove link and connect low range microammeter between the Input Meter binding posts with the — lead to the bottom terminal.

8.3.4 Set Input Polarity slide switch to —.

8.3.5 Set Output Resistor 3 to OFF.

8.3.6 Remove link and connect high range microammeter or low range milliammeter between Output Meter terminals with the — lead to the bottom post.

8.3.7 Set Output Polarity slide switch to —.

8.3.8 Connect a shunt between Output External Load terminals.

8.3.9 Insert the transistor to be tested.

8.3.10 Select the Base current value and collector voltage at which you wish to run the test, either from data sheets or choice. Adjust value of Input Resistor 1, Resistor 2, and Resistor 3 respectively until this adjustment with voltage selected by Input Voltage Selector produces the desired current...and at the same time set Output Voltage Selector to desired collector voltage.

8.3.11 Set the base current to 20 μA lower than the selected value by adjusting Input Resistor 1, Resistor 2, and Resistor 3, and read value on meter connected in step 8.3.3.

8.3.12 Record Collector current read on meter connected in step 8.3.6, as I_{c_1}, at the Base current obtained in Step 8.3.11.

8.3.13 Set the Base current to 20 μA higher than the selected value, by procedure of Step 8.3.11.

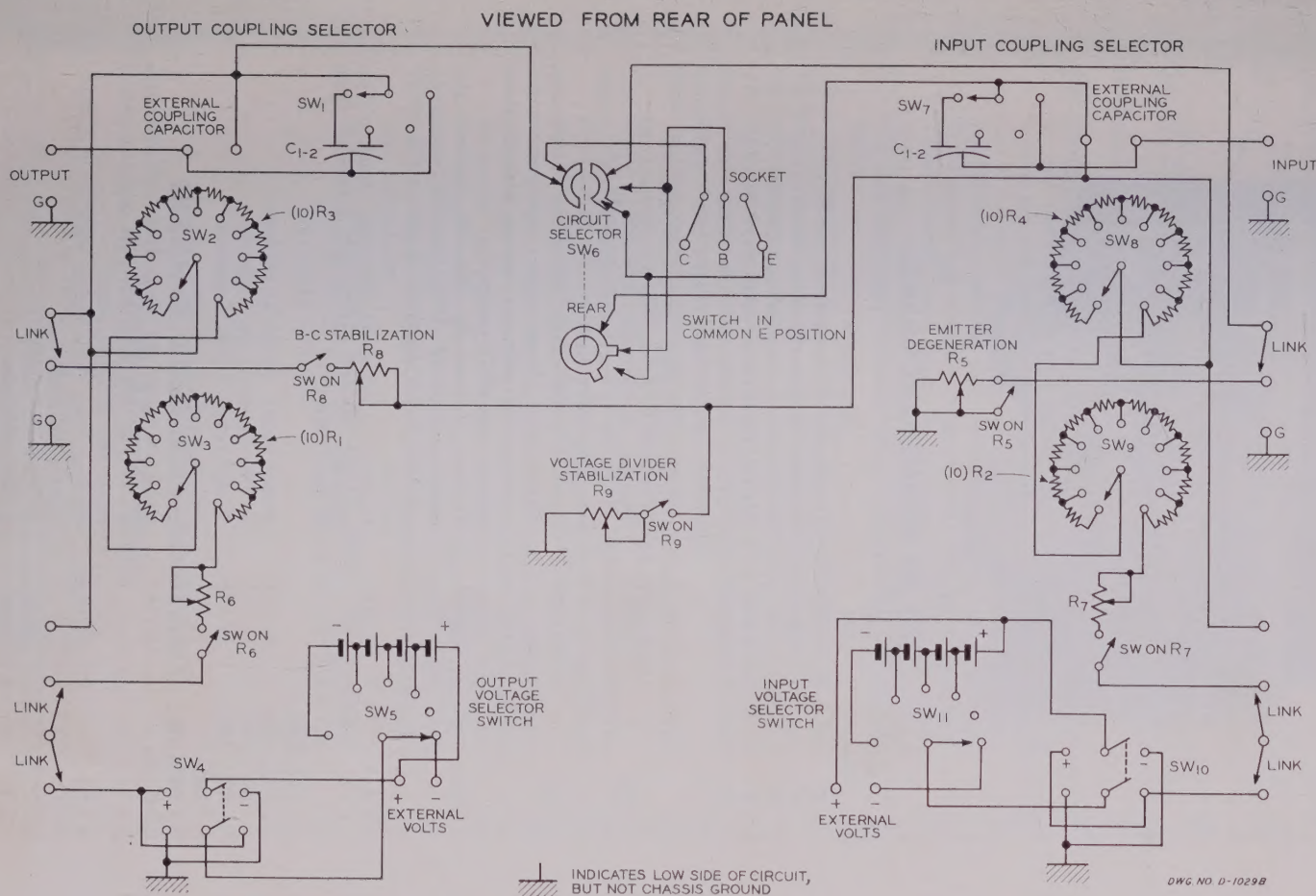
8.3.14 Record the Collector current read on meter connected in step 6, as I_{c_2}, at the Base current obtained in step 8.3.13.

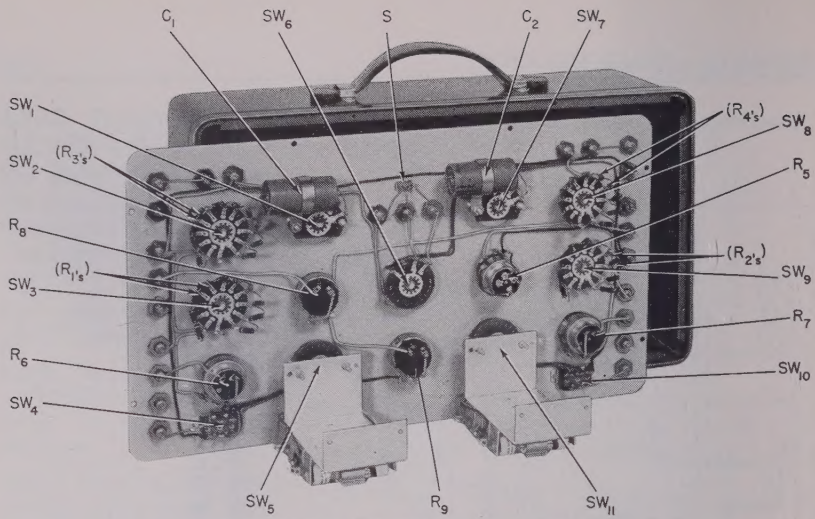
8.3.15 Subtract I_{c_1} from I_{c_2} and divide the difference expressed in μA. by 40 μA or the net change in Base current.

8.3.16 The result will be a number greater than 1, and is Beta (B).

8.3.17 The procedure of steps 8.3.10 through 8.3.16 may be repeated for various levels of Base current, to check variations of Beta at different current levels.

8.3.18 During the above tests, all other elements of the Transimulator not used in the steps above, are maintained in normal position.


VIEWED FROM REAR OF PANEL
OUTPUT COUPLING SELECTOR
INPUT COUPLING SELECTOR
EXTERNAL COUPLING CAPACITOR
SW1
C1-2
SW7
EXTERNAL COUPLING CAPACITOR
C1-2
OUTPUT
INPUT
G
(10) R3
SW2
(10) R4
SW8
CIRCUIT SELECTOR SW6
SOCKET
C
B
E
REAR
SWITCH IN COMMON E POSITION
LINK
B-C STABILIZATION R8
SW ON R8
EMITTER DEGENERATION R5
SW ON R5
(10) R1
SW3
SW9
(10) R2
VOLTAGE DIVIDER STABILIZATION R9
SW ON R9
R6
SW ON R6
R7
SW ON R7
OUTPUT VOLTAGE SELECTOR SWITCH
SW5
INPUT VOLTAGE SELECTOR SWITCH
SW11
SW4
SW10
EXTERNAL VOLTS
EXTERNAL VOLTS
INDICATES LOW SIDE OF CIRCUIT, BUT NOT CHASSIS GROUND
DWG. NO. D-1029B



LIST OF MAINTENANCE PARTS

Circuit Symbol	Part No.	Description
R_1	2-58-5	Resistor, fixed, composition, 2400Ω ±5%, ½W.
R_2	2-66-5	Resistor, fixed, composition, 5100Ω ±5%, ½W.
R_3	2-82-5	Resistor, fixed, composition, 24,000Ω ±5%, ½W.
R_4	2-90-5	Resistor, fixed, composition, 51,000Ω ±5%, ½W.
R_5	2-1060	Resistor, continuously adjustable, wirewound, 2500Ω ±10%, linear taper, 300° mechanical rotation, 260° electrical rotation, precious metal contact, with SPDT switch.
R_6	2-1058	Resistor, continuously adjustable, wirewound, 2500Ω ±10%, otherwise same as part 2-1060 except for SPST switch.
R_7	2-1059	Resistor, continuously adjustable, wirewound, 5000Ω ±10%, linear taper, 300° mechanical rotation, 260° electrical rotation, precious metal contact, with SPST switch.
R_8	2-1061	Resistor, continuously adjustable, molded composition, 250,000Ω ±10%, 2W, 333° mechanical rotation, 312° electrical rotation, with SPST switch.
R_9	2-1062	Resistor, continuously adjustable, molded composition, 50,000Ω ±10%, 2W, otherwise same as part 2-1061.
SW_2, SW_3, SW_8, SW_9	11-178	Switch, rotary, 1 pole, 11 position.
SW_1, SW_7	11-177	Switch, rotary, 1 pole, 4 position.
SW_5, SW_{11}	11-178	Switch, rotary, 1 pole, 6 position.
SW_6	11-176	Switch, rotary, 3 position.
SW_4, SW_{10}	11-82	Switch, slide, DPDT.
C_1, C_2	1-178	Capacitor fixed, dry electrolytic, non-polarized, 2+20μF @ 100 volts d-c, with outer cardboard jacket and mounting strap
BP	15-309B	Binding Post, black, red, or yellow. (Specify color when ordering.)
	12-24	Knob, black, molded.
S	4-35	Socket, transistor.
	1810	Clip, battery

STANDARD MODEL LF-1

WARRANTY

The Sprague Products Company warrants each Transimulator to be free from defective material and workmanship and agrees to remedy any such defect or to furnish a new part in exchange for any part of any unit of its manufacture which under normal installation, use and service discloses such defect, provided the unit is delivered by the owner to us intact, for our examination, with all transportation charges prepaid to our factory or authorized service station within ninety days from the date of sale to original purchaser and provided that such examination discloses in our judgment that it is thus defective.

This Warranty does not extend to any Transimulator which has been subjected to misuse, neglect, accident, incorrect wiring not our own, improper installation, or to use in violation of instructions furnished by us, nor extend to units which have been repaired or altered outside of our factory nor to cases where the serial number thereof has been removed, defaced or changed.

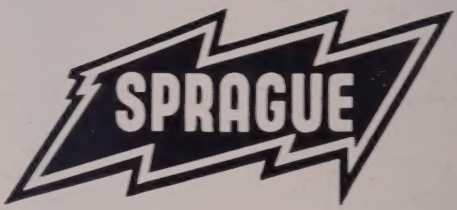
Any part of a unit approved for remedy or exchange hereunder will be remedied or exchanged by us without charge to the owner.

This Warranty is in lieu of all other Warranties expressed or implied and no representative or person is authorized to assume for us any other liability in connection with the sale of our products.

If the return of this instrument is deemed necessary, advise SPRAGUE PRODUCTS COMPANY, NORTH ADAMS, MASS., giving full details. Our reply and complete shipping instructions will reach you within five (5) days after receipt of your letter. NO ADJUSTMENTS WILL BE MADE UNLESS OUR CONSENT FOR THE RETURN OF THE INSTRUMENT IS OBTAINED BEFORE MAKING SHIPMENT.

NOTE: RETURNED INSTRUMENTS MUST BE PACKED CAREFULLY, MARKED FRAGILE, AND SHIPPED BY PREPAID EXPRESS.

SPRAGUE PRODUCTS COMPANY
North Adams, Mass.



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E-1-61

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